Legacy Waveforms on Software Defined Radios: Benefits of Advanced Digital Signal Processing

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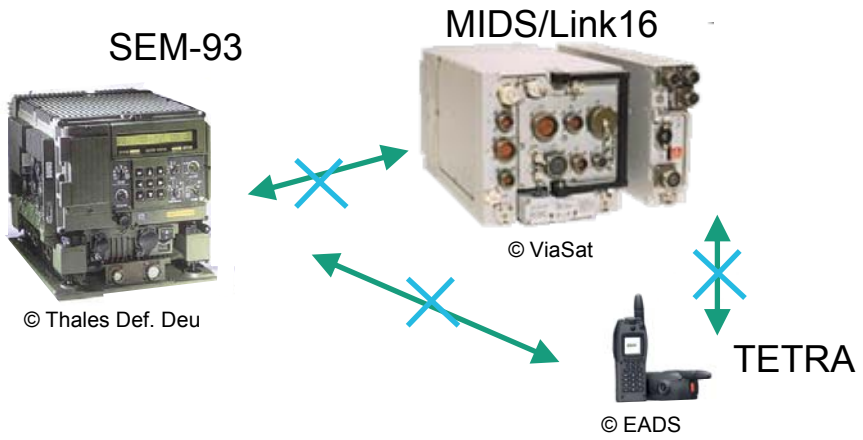
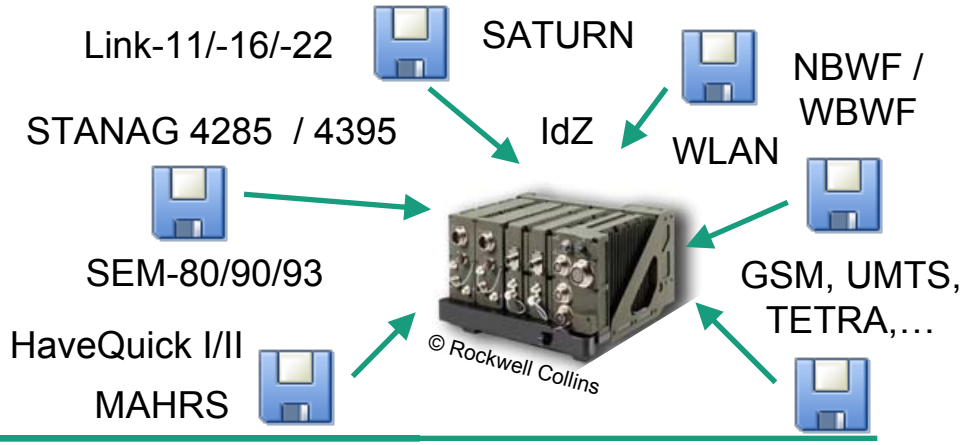
Conventional Radio Equipment vs. Software Defined Radio

- Conventional Radios
  - limited interoperability
  - new system specification ↔ new radio equipment
  - high service & maintenance costs



- Software Defined Radio

Considerable parts of signal processing are realized as software programms on programmable and/or reconfigurable hardware.



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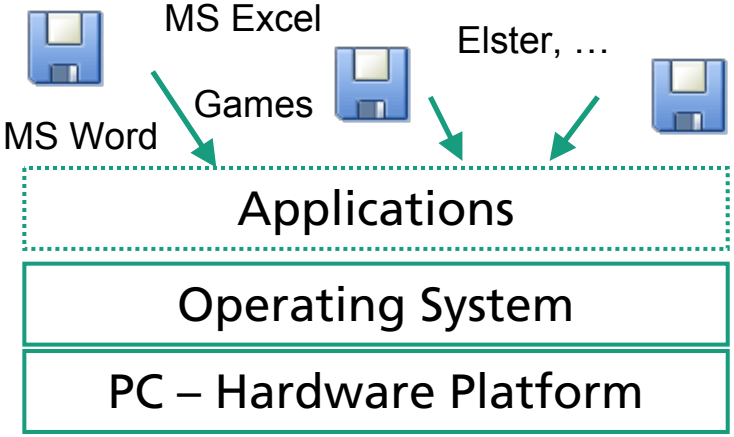
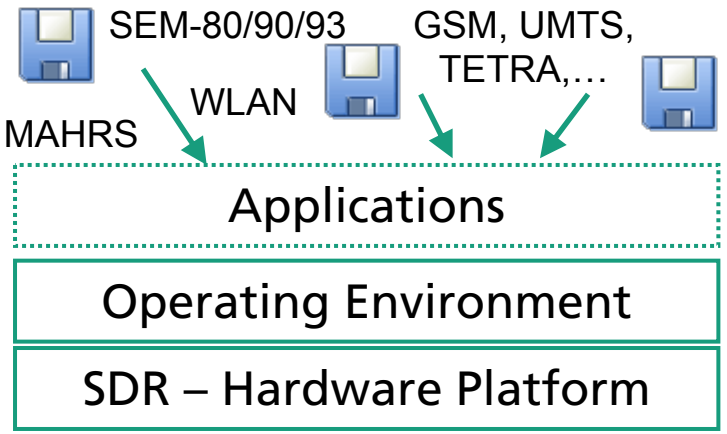
Analogies: PCs vs. Software Defined Radio

- On first glance …





… but, SDRs are much more complex !!!

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Motivation (1/2)

- Before new wideband networking waveforms are available
- Key challenge

Concepts for Porting Legacy Waveforms to Software Defined Radios

Portability [IEEE]

the ease with which a system or component can be transferred from one hardware or software environment to another

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Legacy Radio

© Rockwell Collins

Software Defined Radio

Motivation (2/2)

- Different concepts
  - one-to-one porting of signal processing → guaranteed interoperability
  - introduce novel receiver signal processing → keep interoperability
  - introduce novel transceiver signal processing
    → no interoperability to legacy radios, but to other SDRs

Legacy Radio

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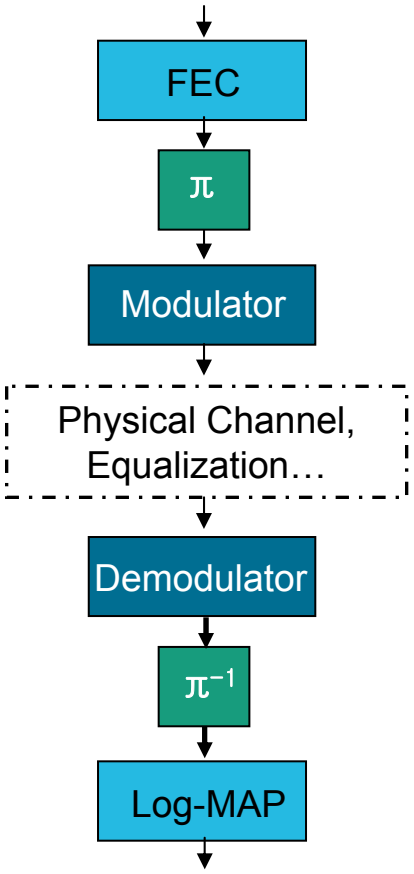
Software Defined Radio

- Example: MIL-STD-188-110B Serial Single Tone Waveform

MIL-STD-188-110B Serial Single Tone

- US DoD *"Interoperability and Performance Standards for Data Modems"*



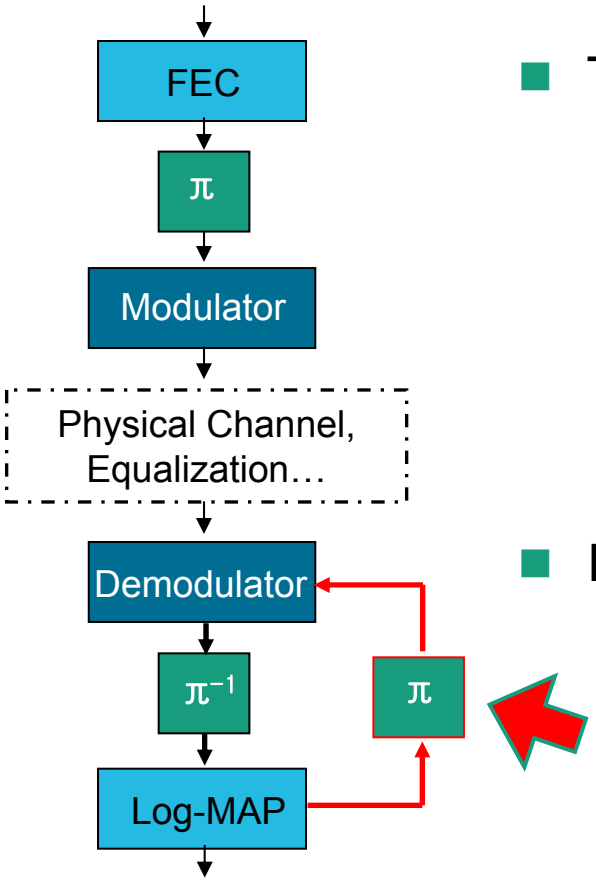
- Some details
  - this mode was specified in 1991(MIL-STD-188-110A)
  - configurations:

Datarate (bps)	Method for achieving the code rate	Modulation
4800	No coding	8-PSK
2400	**G(171,133), r = ½**	**8-PSK**
1200	G(171,133), r = ½	QPSK
600	G(171,133), r = ½	BPSK
300	G(171,133), r = ½ repeated 2 times	BPSK
150	G(171,133), r = ½ repeated 4 times	BPSK
75	G(171,133), r = ½ plus 8 Walsh-code	BPSK

Blocktype-Interleaver: short l_S=2880 bits & long l_L=23040 bits

BICM-ID: Basic Concept

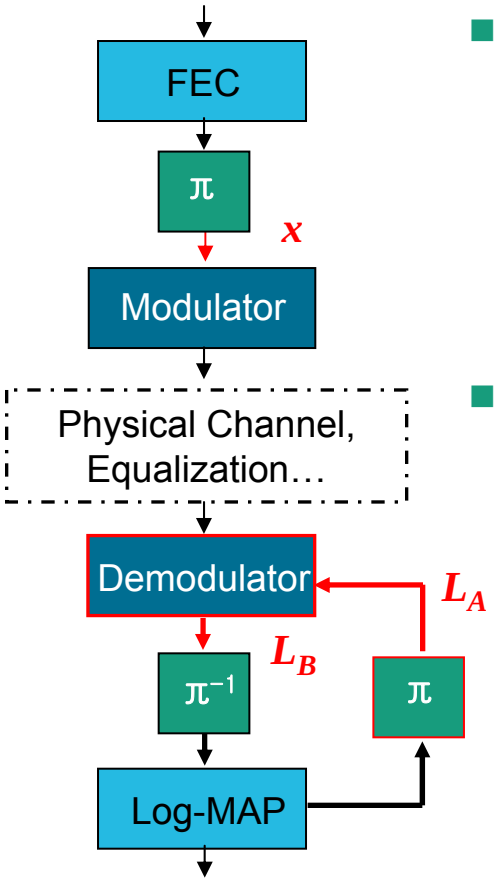
- *Bit Interleaved Coded Modulation with Iterative Decoding*



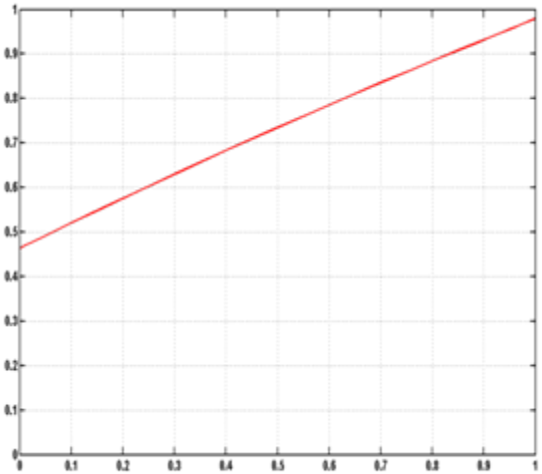
- Transmitter
  - connects coded bits, originally far apart in the sequence, to one channel symbol
  - coded bits forming one symbol are mutually independent
- Receiver
  - demodulator and decoder exploit reliabilities using soft-input-soft-output (SISO) techniques
  - new: iterative feedback of extrinsic information

EXIT-Charts: Basic Concept

- *Extrinsic Information Transfer Charts*



- EXIT-Charts
  - visualize extrinsic information transfer from the extrinsic input of a SISO decoder to the extrinsic output
  - help to understand the convergence behavior
- Example



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EXIT-Charts: Basic Concept

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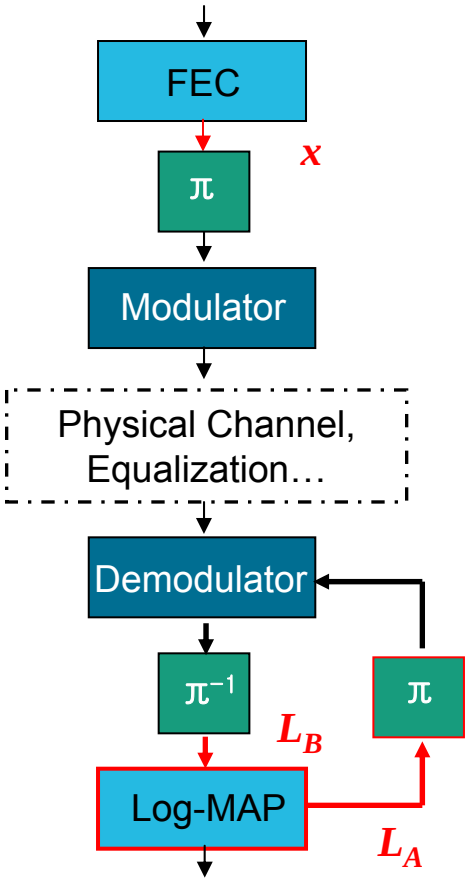

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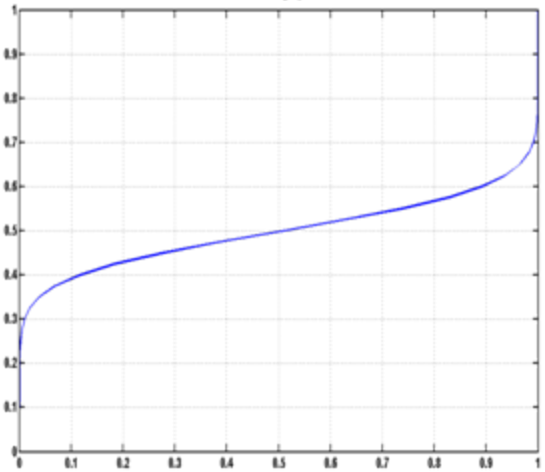

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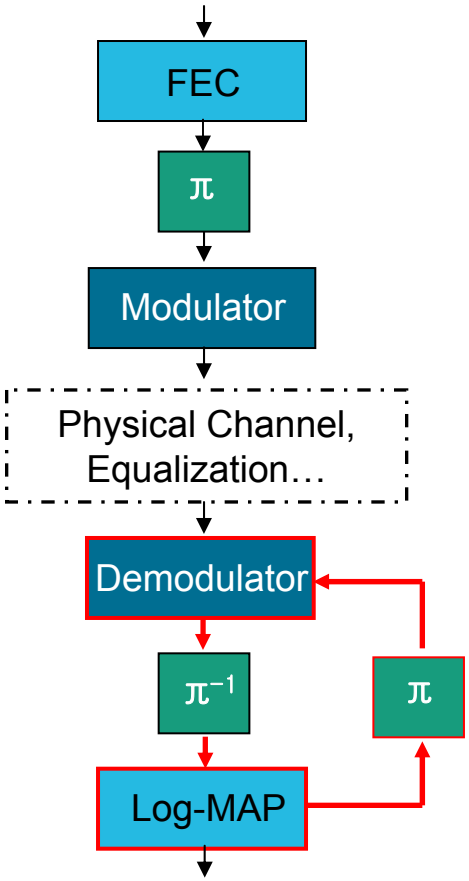

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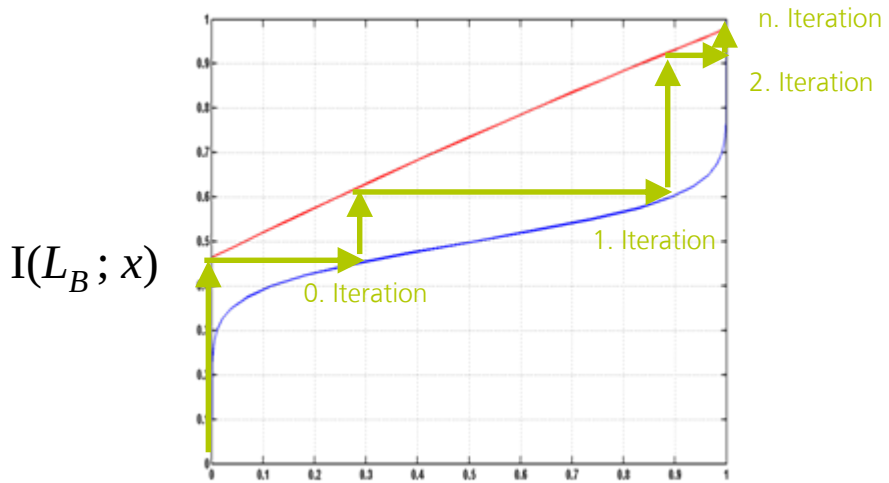

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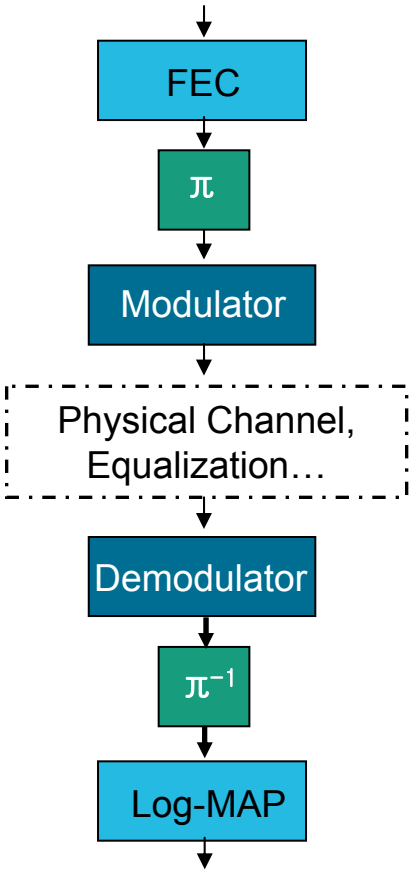
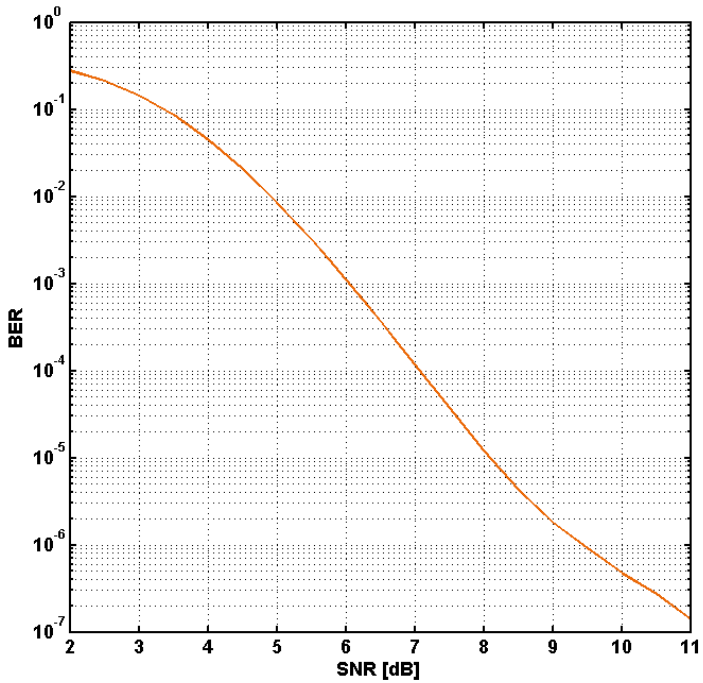
Simulation Results

- *Classic Approach - Straight forward implementation without BICM-ID*





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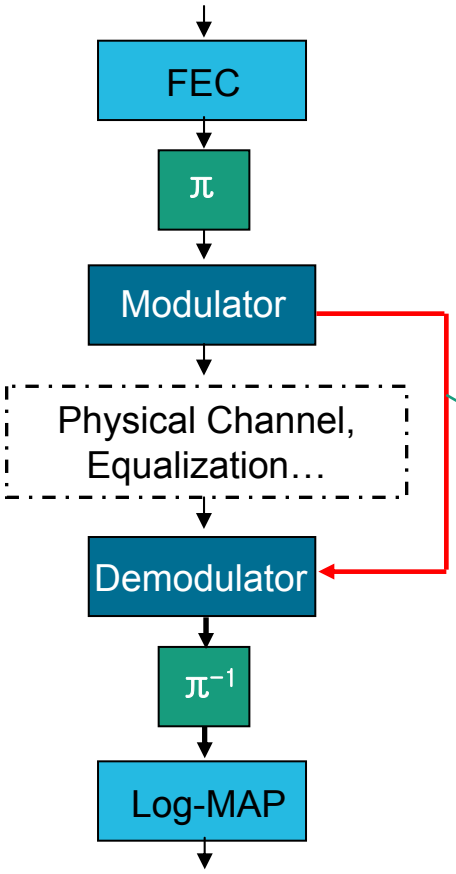
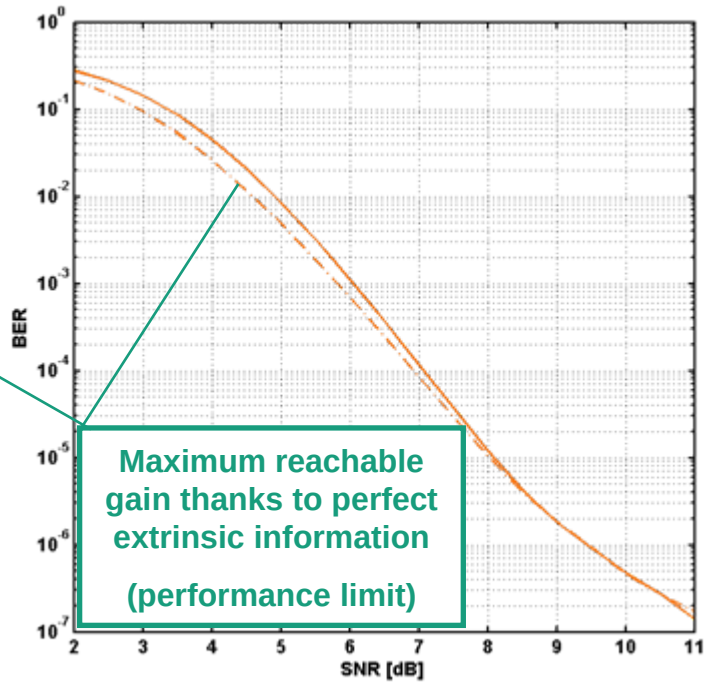
Simulation Results

- *Enhanced Approach - Implementation with BICM-ID*





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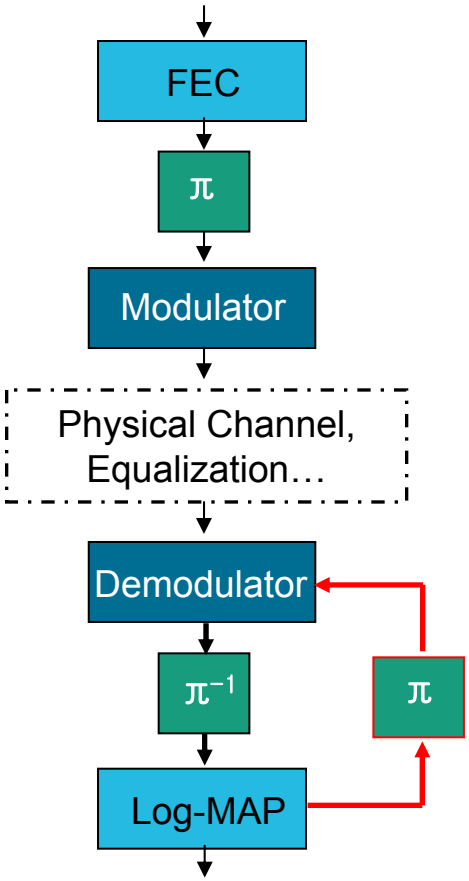

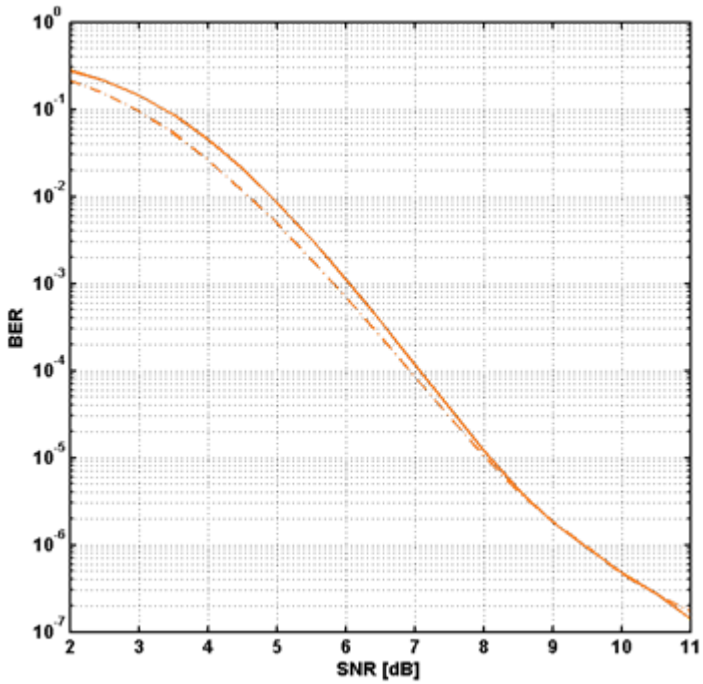

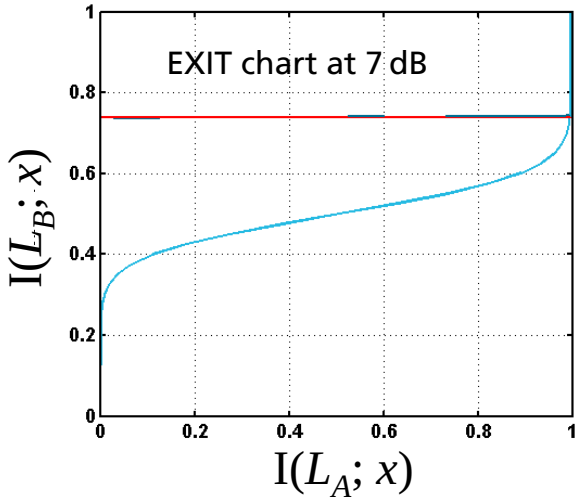

Standard compliant implementation offers only small gains using BICM-ID

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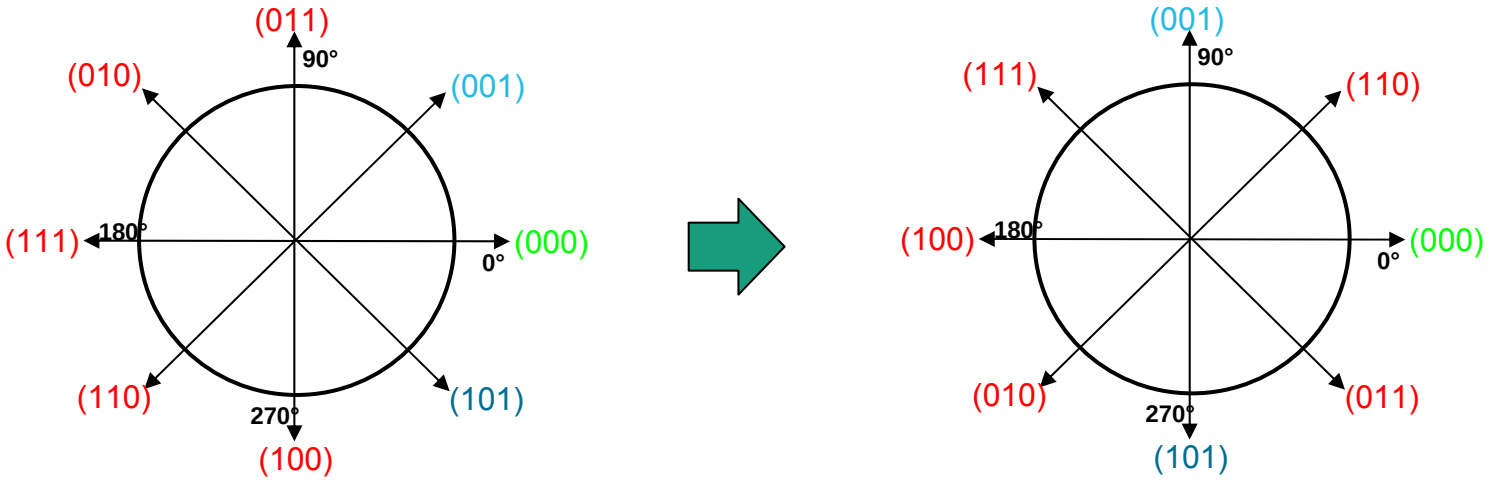
Proposed SDR-Modes

- *Small modification offers substantial performance improvements*

- Proposed modification
  - change mapping from Modified Gray-coding to Semi-Set Partitioning
  - neighboring signal constellation points are as dissimilar as possible
  - usually, only a single line of software code needs to be changed



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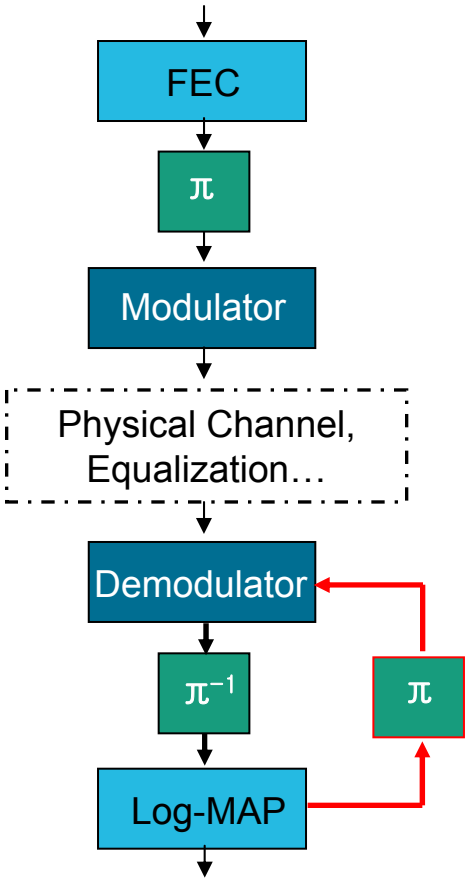
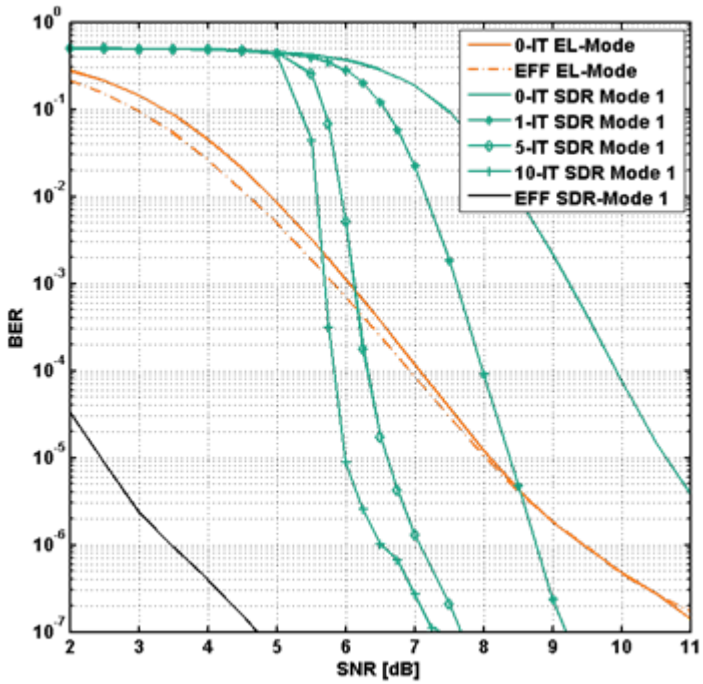
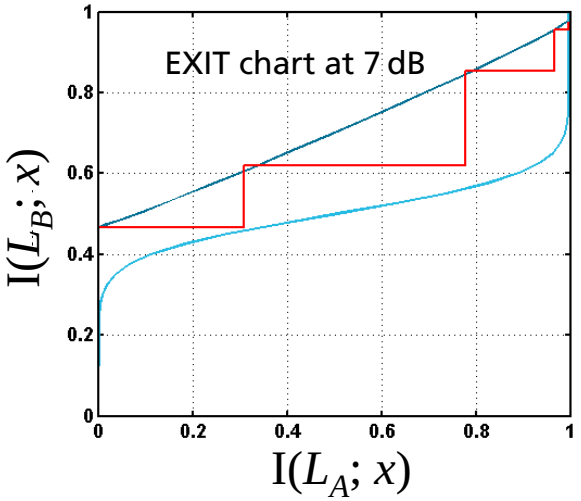
Simulation Results

- *Proposed SDR-Mode with BICM-ID and SSP Labeling*







Proposed SDR-Mode (change of labels) **offers significant gains using BICM-ID**

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Simulation Results

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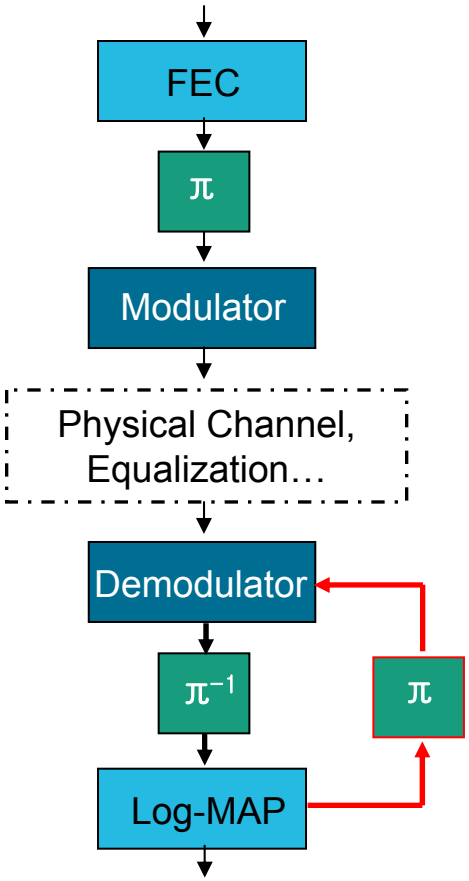

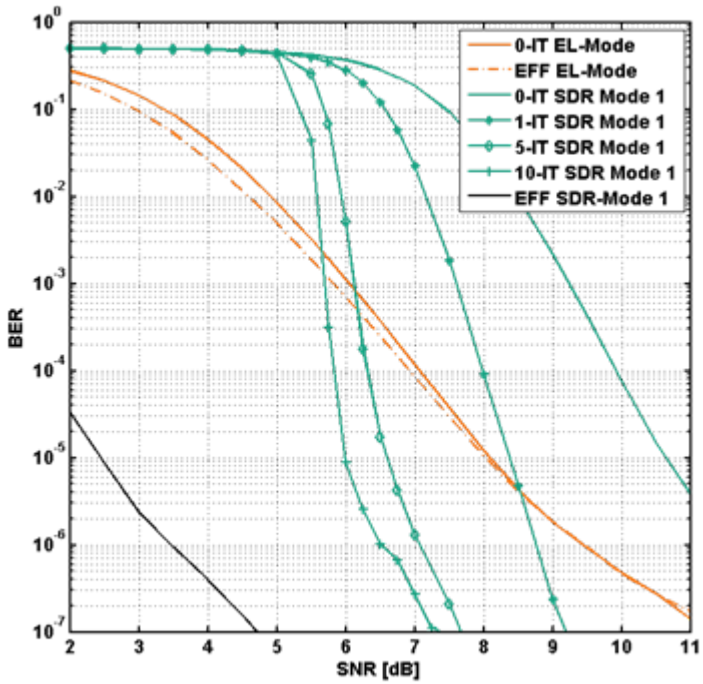

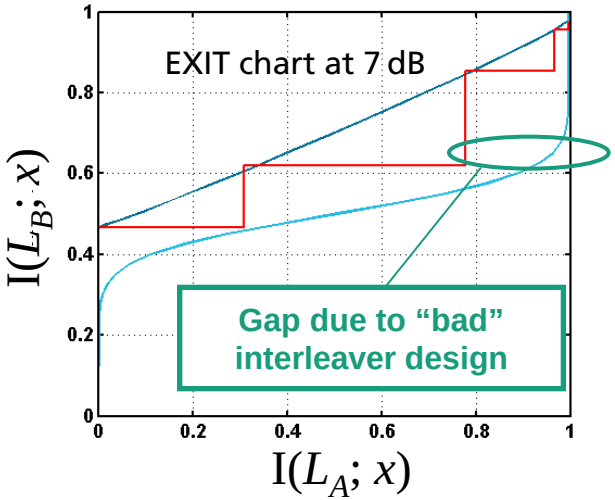

Proposed SDR-Mode (change of labels) **offers significant gains using BICM-ID**

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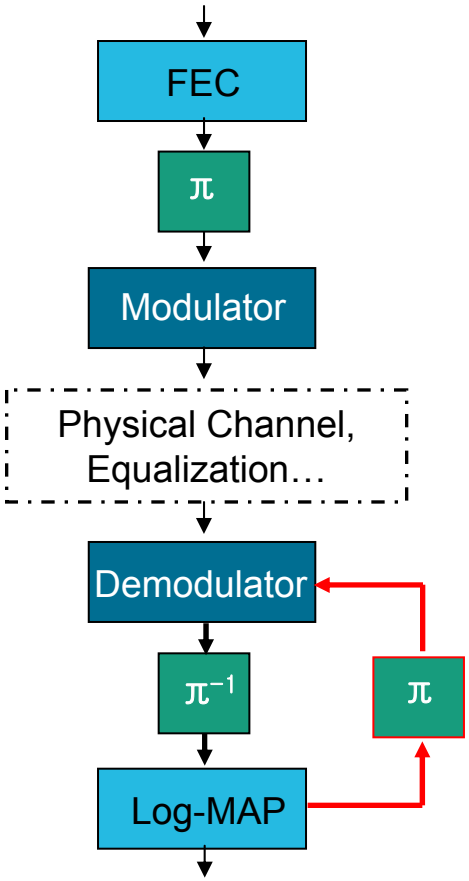
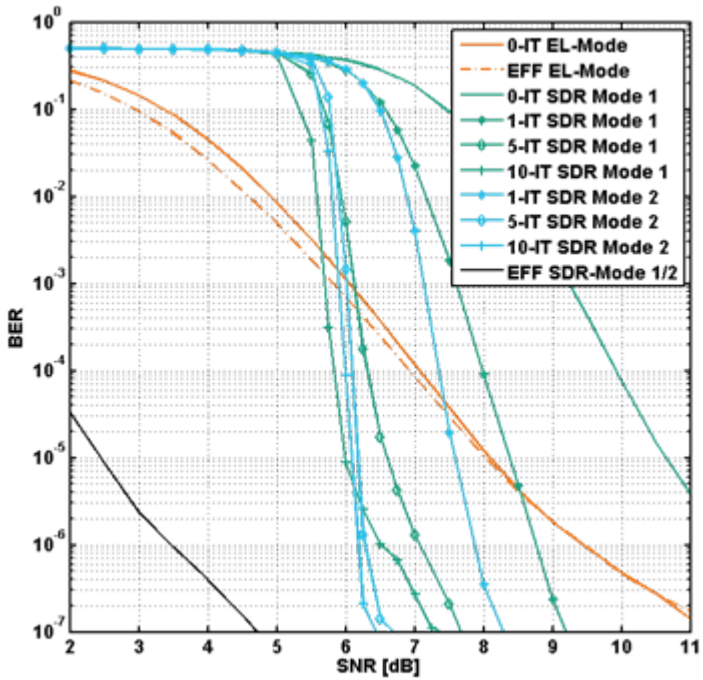
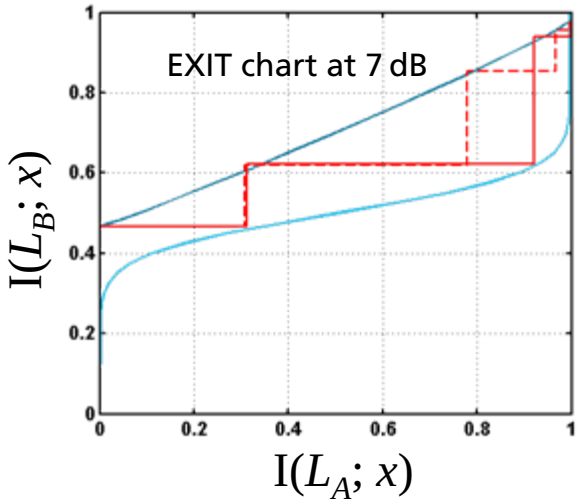
Simulation Results

- *Proposed SDR-Mode with BICM-ID, SSP Labeling and S-Rand Interleaver*







Change of interleaver design offers additional gains using BICM-ID

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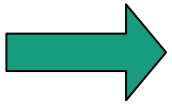
Conclusion

Do recent advances in digital receiver design reveal benefits ?

- A waveforms error robustness can be increased significantly, if novel signal processing is applied
- New SDR platforms are able to offer increased processing demands
- Straight-forward implementation of BICM-ID offers only small gains
- New SDR-Modes are not interoperable to the legacy WF on the air interface, but can perform significantly better

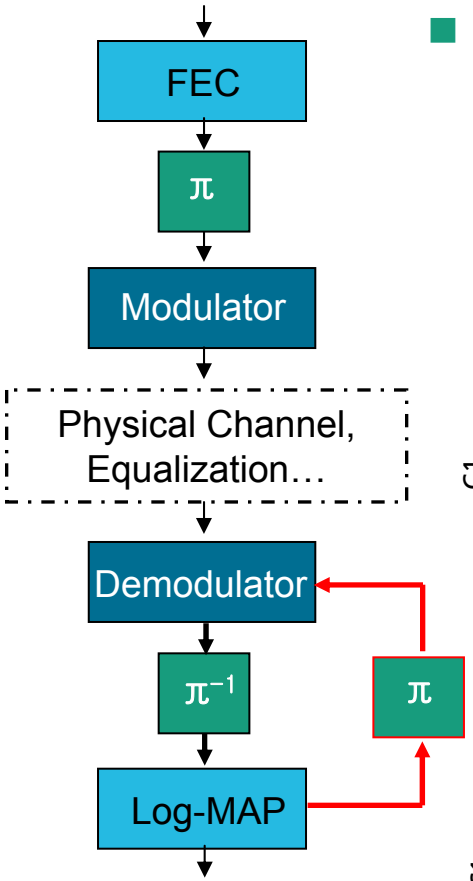


Yes, porting the PHY-functionalities in a one-to-one manner is not always appropriate, minor changes can reveal major performance gains!

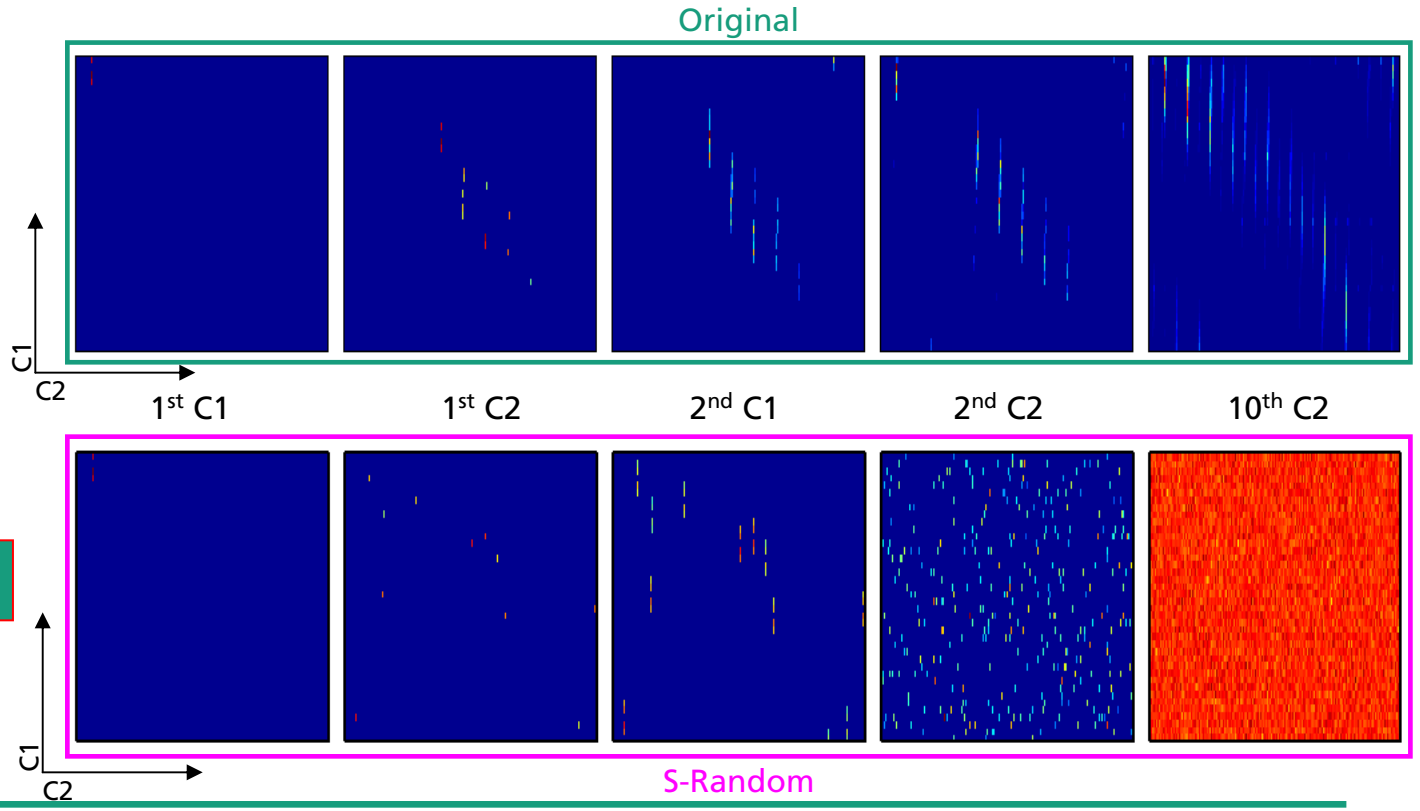
Thanks for your Attention!

Questions or Comments?

Interleaver Influence



- The Interleaver preserves independence of the concatenated decoders and spreads therewith the sources of extrinsic information



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